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(54) Electrostatic-magnetic lens arrangement

(57) The invention relates to an electrostatic-magnetic lens arrangement for focusing charged particles as well as a charged particle beam device with such a lens arrangement which has a magnetic lens and an electrostatic lens incorporated into the magnetic lens, the magnetic lens being constructed as a single-pole lens.

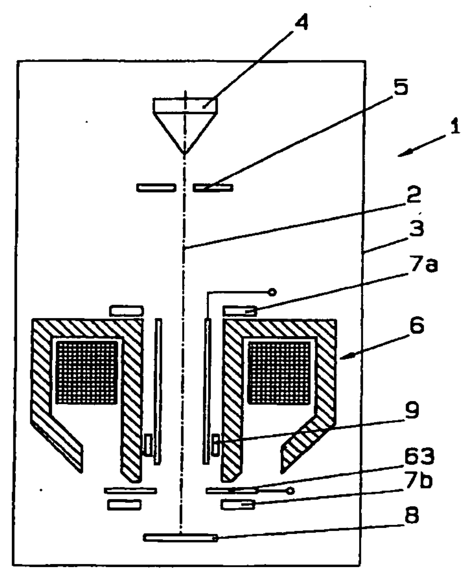

Fig. 1

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Description

The invention relates to an electrostatic-magnetic lens arrangement for focusing charged particles with a magnetic lens and an electrostatic lens disposed incorporated into the magnetic lens. The invention further relates to a charged particle beam device with such an electrostatic-magnetic lens arrangement.

An electrostatic-magnetic lens arrangement according to the preamble of Claim 1 is known from EP-B-0 242 602, in which there are provided a magnetic lens which generates a rotationally symmetrical magnetic field and an immersion lens which is disposed within the magnetic lens symmetrically with the axis of symmetry thereof and which has at least two electrodes lying at different potentials. The charged particles, for example electrons, are decelerated in the field of the immersion lens from a first energy to a substantially lower second energy. Very good lens properties are produced with a relatively short focal length.

However, in this known lens arrangement the specimens must be disposed very close to the magnetic lens during the measurement. However, this is often no longer possible in the case of high specimens like specimens with ICs and associated sockets. An arrangement of the specimen close to the magnetic lens is also limited by the design of the specimen holder. Since on the one hand the specimen has to be contacted during measurement and on the other hand simple exchange of the specimens must be ensured, a greater working distance with good resolving and imaging properties would be desirable.

A charged particle beam device which provides a single-pole lens for focusing the particles is known from GB-B-1 395 201. In contrast to a bipolar lens, in the single-pole lens the magnetic field is essentially generated outside the lens, so that greater working distances can be achieved. Such single-pole lenses are distinguished by relatively good lens properties. However, if such lenses are used in the low voltage range, i.e. at final beam energies of the charged particles of less than 5 keV, preferably below 2.5 keV, the lens properties are too poor for many applications at working distances of more than 5 mm.

The object of the invention, therefore, is to provide an electrostatic-magnetic lens arrangement according to the preamble of Claim 1 as well as a charged particle beam device according to the generic concept of Claim 12 which is distinguished particularly in the low voltage range by a great working distance and good lens properties.

This object is achieved according to the invention by the characterising features of Claims 1 and 12, by the construction of the magnetic lens as a single-pole lens within which an electrostatic lens is located.

The single-pole lens can be combined particularly advantageously with an electrostatic lens, in which case attention must be paid to ensure that the field generated by the electrostatic lens is not so strong that it alone is sufficient to focus the beam. With the lens arrangement according to the invention working distances of more than 5 mm, particularly between 5 and 30 mm, can be achieved.

In a further preferred embodiment the lens arrangement has an additional control electrode which is situated in the beam path between the electrostatic lens and a specimen. This control electrode can be connected to a variable potential in order to be able to adjust the electrical field strength in the region of the specimen. For specimens which are particularly sensitive to charging it is then possible to achieve field cancellation in the region of the specimen.

Further embodiments of the invention are the subject matter of the subordinate claims and are explained in more detail below with reference to the description and the drawings.

In the drawings:

Figure 1 shows a schematic representation of a charged particle beam device according to the invention.

Figure 2 shows a schematic representation of a lens arrangement according to the invention, and

Figure 3 shows a schematic representation of two variants of the single-pole lens.

Figure 1 shows a charged particle beam device with which a concentrated particle beam 2, for example an electron beam, can be generated in an optical column 3. In addition to a number of magnetic and/or electrical lenses and diaphragms (not shown here) for beam formation, this column 3 essentially has a source 4 for generating the particle beam 2, a lens arrangement 6 as well as at least one detector 7a or 7b. A blanking system 5 could also be provided for blanking the charged particle beam.

The particle beam 2 generated in the source 4 is focused by the electrostatic-magnetic lens arrangement 6 onto a specimen 8. The particles emitted there pass through the lens arrangement 6 to the detector 7a. However, instead of the detector 7a a detector 7b could also be provided between the specimen 8 and the electrostatic-magnetic lens arrangement 6. To further improve the evaluation of the secondary or the back-scattered particles both the detector 7a and the detector 7b could be provided in a particle beam device. In this case at least one of the two detectors could also be of segmented construction, so that the detector surface is divided into segments the output signals of which can be processed separately from one another.

For scanning the specimen with the particle beam 2 a deflector arrangement 9 is also provided which in the illustrated embodiment is disposed within the lens arrangement 6.

The lens arrangement 6 according to the invention is explained in greater detail below with reference to

Figure 2. It consists essentially of a magnetic lens constructed as a single-pole lens 61 as well as an electrostatic lens 62 which is situated within the magnetic lens and generates a rotationally symmetrical electrical field.

This electrostatic lens has two electrodes held at different potentials, and these electrodes can have different potentials applied to them such that the charged particles, for example the electrons, are decelerated in the field of the electrostatic lens from a first energy to a lower second energy. In this case the first energy is 1.2 to 10 times higher than the second energy, in order to achieve the greatest possible working distance with good resolving and imaging properties.

In the illustrated embodiment one of the two electrodes is formed by a cylindrical beam tube 62a which is situated concentrically in an internal bore 61a in the single-pole lens 61. The beam tube 62a is preferably made from non-conductive material which is coated with a thin conductive layer. The second electrode of the electrostatic lens is formed by the lower end of the inner pole piece 61b held at earth potential. However, it could also be provided as a separate electrode. The second electrode does not, however, have to be at earth potential, but can also be set at another potential.

The single-pole lens 61 illustrated in Figure 2 has an inner pole piece 61b as well as an outer pole piece 61c which are of essentially cylindrical shape. A field coil 61d is provided for excitation of the magnetic lens.

An additional control electrode 63 is provided in the beam path between the electrostatic lens 62 and the specimen 8 and is connected to a variable voltage source, which is not shown in greater detail, in order to be able to adjust the electrical field strength in the region of the specimen. The voltage on the control electrode can for example be adjusted between -100 V and +100 V.

The deflector arrangement 9 is preferably constructed as a single-stage deflector arrangement and provided between the beam tube 62a and the wall delimiting the internal bore 61a of the single-pole lens 61.

The charged particle beam device also has a vacuum facility for generating a vacuum in the region of the particle beam. In order to be able better to dissipate the heat generated by the deflector arrangement a seal 11 is preferably provided between the beam tube 62a and the single-pole lens 61 so that the deflector arrangement 9 is surrounded by air and thus an improved heat dissipation is ensured. Equally advantageously, a further seal 12 can be provided in the single-pole lens 61 to shield the field coil 61d from the vacuum.

With the aid of the electrostatic lens 62 the charged particles are decelerated to a final beam energy of lower than 5 keV, preferably between 0.5 and 2.5 keV, a working distance of more than 5 mm being produced between the specimen 8 and the lens arrangement 6. The working distance a is formed here by the distance between the specimen 8 and the control electrode 63.

According to the invention the distance between the control electrode 63 and the specimen 8 (= working distance a) is at least three times the distance b between the control electrode 63 and the single-pole lens 61. The control electrode 63 has an opening 63a, the diameter d_1 of which is less than double the diameter d_2 of the single-pole lens 61. This condition is necessary for sufficient shielding of the field in the region of the specimen. Furthermore the diameter d_1 of the opening 63a of the control electrode 63 should be at least half as great as the diameter d_3 of the beam tube 62a. Otherwise the particles emitted from the specimen 8 are not guaranteed to reach the detector 7a disposed above the lens arrangement 6.

Two further embodiments of single-pole lenses 61', 61" are shown in Figure 3. The embodiment on the right shows a single-pole magnetic lens 61' with an outer pole piece 61'c which is at least partially conical. In the single-pole lens 61" shown in the left-hand side the outer pole piece has been removed entirely.

The charged particle beam device according to the invention is designed particularly for the low voltage range, i.e. for final beam energies lower than 5 keV, preferably between 0.5 and 2.5 keV. A particularly suitable source for this purpose is a so-called field emission source or other sources with an energy width of less than 1 eV, for example thermal field emission sources or photo cathodes. With the combination according to the invention of an electrostatic lens with a single-pole lens particularly great working distances can be achieved for the low voltage range with good resolving and imaging properties. Thus in particular specimen holders can also be used which have contacting means protruding above the specimen.

Claims

1. Electrostatic-magnetic lens arrangement for focusing charged particles with a magnetic lens and an eletrostatic lens (62) situated within the magnetic lens, characterised in that the magnetic lens is constructed as a single-pole lens (61, 61', 61").

2. Lens arrangement as claimed in Claim 1, characterised in that the electrostatic lens (62) generates a rotationally symmetrical electrical field and has at least two electrodes (62a, 61b) which can be held at different potentials such that the charged particles are decelerated in the field of the electrostatic lens from a first energy to a lower second energy.

3. Lens arrangement according to Claim 2, characterised by an additional control electrode (63) which is situated in the beam path between the electrostatic lens and a specimen (8) and can be connected to a variable potential for adjustment of the electrical field strength in the region of the specimen.

4. Lens arrangement as claimed in one of the preceding claims, characterised in that at a final beam

energy of the charged particles of less than 5 keV, preferably between 0.5 and 2.5 keV, a working distance (a) of more than 5 mm is provided between the lens arrangement and the specimen (8).

5. Lens arrangement as claimed in Claim 3, characterised in that the distance (a) between the control electrode (63) and the specimen (8) is at least three times the distance (b) between the control electrode (63) and the single-pole lens (61).

6. Lens arrangement as claimed in Claim 2, characterised in that one of the two electrodes of the electrostatic lens is constructed as a beam tube (62a).

7. Lens arrangement as claimed in Claim 6, characterised in that the beam tube (62a) is made from non-conductive material which is provided with a thin conductive coating.

8. Lens arrangement as claimed in Claim 6, characterised in that the beam tube (62a) is situated concentrically in an internal bore (61a) of the single-pole lens (61).

9. Lens arrangement as claimed in Claim 3, characterised in that the single-pole lens (61) has an internal bore (61a) and the control electrode (63) has an opening (63a), the diameter (d_1) of the control electrode (53) being less than double the diameter (d_2) of the single-pole lens (61).

10. Lens arrangement as claimed in Claim 1, characterised in that the single-pole lens (61) has an inner and an outer pole piece (61b, 61'c), the outer pole piece (61'c) being at least partially conical in shape.

11. Lens arrangement as claimed in Claim 3 and 6, characterised in that the control electrode (63) has an opening (63a) the diameter (d_1) of which is at least half as great as the diameter (d_3) of the beam tube (62a).

12. Charged particle beam device with

a) a source (4) for generating a charged particle beam,

b) an electrostatic-magnetic lens arrangement (6) for focusing the particle beam having a magnetic lens and an electrostatic lens (62) incorporated into the magnetic lens,

c) a deflector arrangement (9) for deflecting the particle beam, and

d) a detector (7) for detecting the secondary and/or back-scattered particles emitted from the specimen (8)

characterised in that the magnetic lens is constructed as a single-pole lens (61, 61', 61").

13. Charged particle beam device as claimed in Claim 12, characterised in that the electrostatic-magnetic lens arrangement (6) is constructed as claimed in one of Claims 2 to 11.

14. Charged particle beam device as claimed in Claim 12, characterised in that the electrostatic lens generates a rotationally symmetrical field and has at least two electrodes (62a, 61b) which can be held at different potentials such that the charged particles are decelerated in the field of the electrostatic lens from a first energy to a lower second energy and wherein one of the two electrodes of the electrostatic lens is constructed as a beam tube (62a) which is arranged concentrically in an internal bore (61a) of the single-pole lens (61).

15. Charged particle beam device as claimed in Claim 14, characterised in that the deflector arrangement (9) is situated in the single-pole lens (61) between the wall of the internal bore (61b) and the beam tube (62a).

16. Charged particle beam device as claimed in Claim 12, characterised in that a vacuum facility is provided for generating a vacuum in the region of the particle beam.

17. Charged particle beam device as claimed in Claim 15 and 16, characterised in that a seal (11) is provided between the beam tube (62a) and the single-pole lens (61) such that the deflector arrangement (9) is situated outside the vacuum.

18. Charged particle beam device as claimed in Claim 16, characterised in that the single-pole lens (61) has a field coil (61d) which is shielded from the vacuum by means of a further seal (12) provided on the single-pole lens (61).

19. Charged particle beam device as claimed in Claim 12, characterised in that the detector (7a) is arranged in front of the electrostatic-magnetic lens arrangement (6) in the direction of the particle beam.

20. Charged particle beam device as claimed in Claim 12, characterised in that the detector (7b) is arranged behind the lens arrangement (6) in the direction of the particle beam.

21. Charged particle beam device as claimed in Claim 19 and 20, characterised in that a detector (7a) is provided in front of the lens arrangement and a detector (7b) is provided behind the lens arrangement (8).

22. Charged particle beam device as claimed in one of Claims 12, 19, 20, 21, characterised in that at least one of the detectors (7a, 7b) is divided into segments the output signals of which can be processed separately from one another.

23. Charged particle beam device as claimed in Claim 12, characterised in that a source with an energy width of less than 1 eV is used.

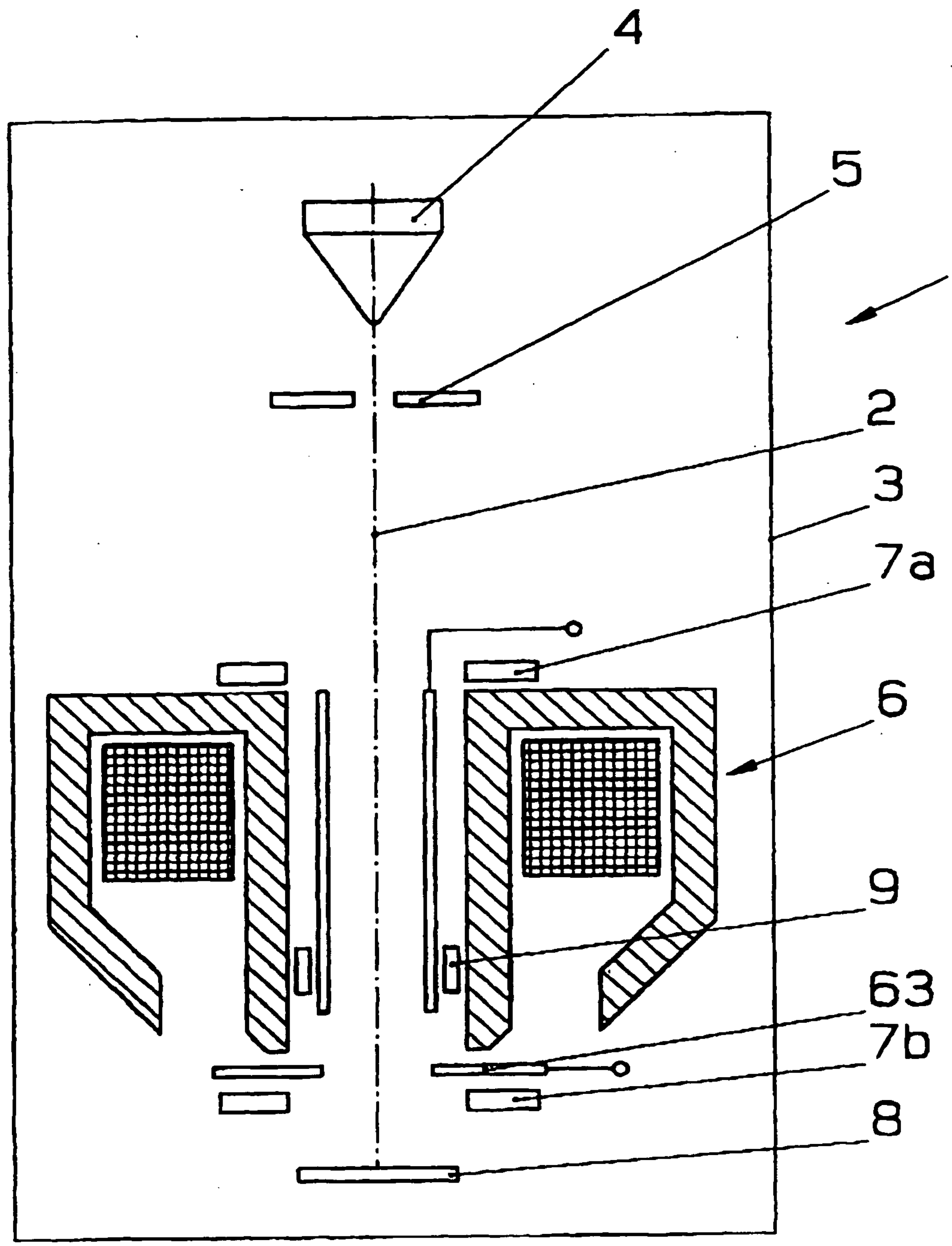

Fig.1

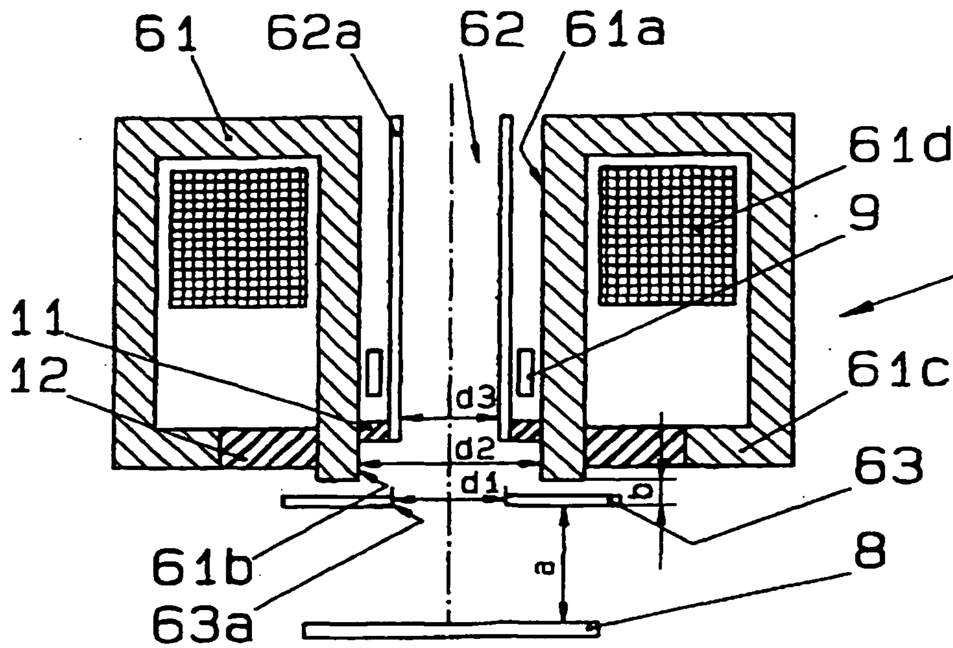
61
62a
62
61a
61d
9
6
11
12
61c
d3
d2
d1
b
63
a
61b
63a
8

Fig.2

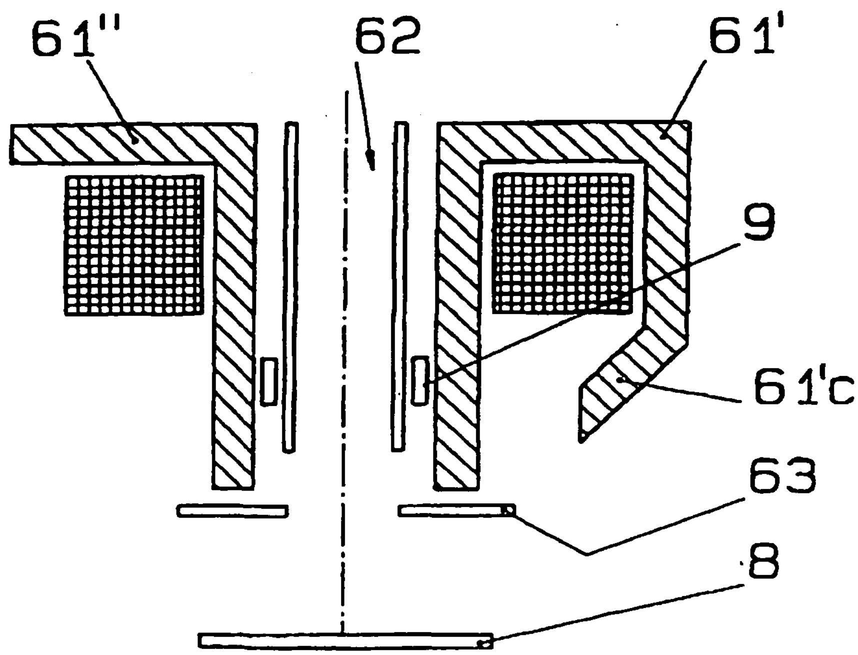
61''
62
61'
9
61'c
63
8

Fig.3

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EUROPEAN SEARCH REPORT

Application Number
EP 96 11 0765

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y	US-A-5 241 176 (YONEZAWA AKIRA) 31 August 1993 * column 4, line 53 - column 5, line 58; figure 1 * ---	1,2,4, 12-16,19	H01J37/145
Y	WO-A-91 02374 (SEIKO INSTR INC) 21 February 1991 * abstract; figures * ---	1,2,4, 12-16,19	
A	JOURNAL OF VACUUM SCIENCE AND TECHNOLOGY: PART B, vol. 7, no. 6, 1 November 1989, pages 1874-1877, XP000117179 FROSIEN J ET AL: "COMPOUND MAGNETIC AND ELECTROSTATIC LENSES FOR LOW-VOLTAGE APPLICATIONS" * page 1875, right-hand column, paragraph 2 - page 1876, right-hand column, paragraph 2; figures 2,5,6 * ---	1,12	
D,A	EP-A-0 242 602 (SIEMENS AG) 28 October 1987 * column 2, line 45 - column 3, line 51; figures * ---	1,2,6,7, 12-14	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H01J
A	GB-A-2 052 147 (PHILIPS NV) 21 January 1981 * abstract; figures * -----	3	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	12 December 1996	Schaub, G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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